3.6 RAPIDLY VARIED UNSTEADY FLOWS (POSITIVE AND NEGATIVE SURGES)

A surge or surge wave is a moving wave front which brings about an abrupt change in depth of flow. A surge is also often referred to as moving hydraulic jump and is caused by sudden increase or decrease in flow, such as that caused by sudden opening or closing of a gate fixed in the channel. Surges are usually classified as positive surges and negative surges. A positive surge is one which results in an increase in the depth of flow and a negative surge causes a decrease in the depth of flow.

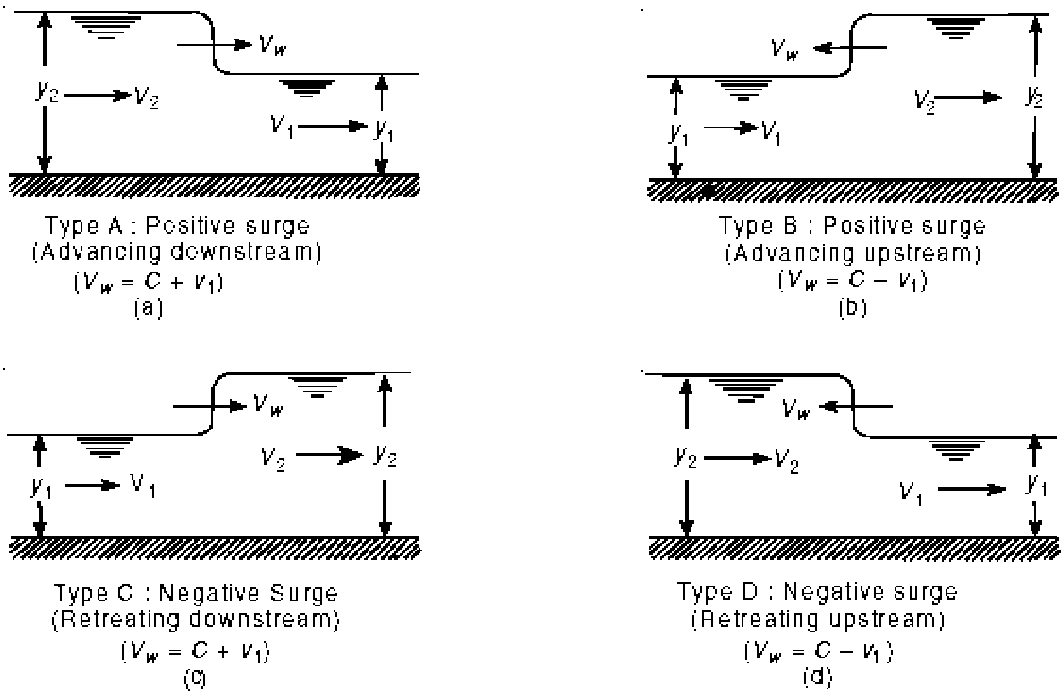

Figure 3.3 Types of hydraulic jump

[*Source: Hydraulics And Fluid Mechanics Including Hydraulic Machines By Dr. P.N.Modi , page 808*]

Figures (a) and (b) shows two types of positive surges and Figs. (c) and (d) shows two types of negative surges. Type A (Fig a) is a positive surge having an advancing wave front moving downstream. Type *B* (Fig. b) is also a positive surge having an advancing wave front moving upstream.Type *C* (Fig. c) is a negative surge having a retreating wave front moving downstream. Type *D* (Fig. d) is also a negative surge having a retreating wave front moving upstream. The positive surge of type *A* may occur when a gate provided at the head of a channel is suddenly opened. The positive surge of the type *B* may occur when a gate provided at the tail end of a channel is suddenly closed. The negative surge of type *C* may occur when a gate provided at the head of a channel is suddenly closed. The negative surge of type *D* may occur when a gate provided at the tail end of a channel is suddenly opened. Although the occurrence of a surge is an usteady flow phenomenon, but when the surge is moving at a constant velocity, it can be converted into a case of a steady flow by applying a velocity of the same magnitude but in opposite direction to the flowing stream as well as to the surge.

Positive Surges

Case (a) Surge due to sudden increase of flow

Consider a positive surge of type A created in a rectangular channel by suddenly opening a gate. Let Vw be the absolute velocity of the surge moving towards right and let V1 and V2 be the velocities and y1 and y2 be the corresponding depths at sections 1 and 2 respectively. In order to make it a case of steady flow, apply velocity Vw in opposite directions to the velocities V1 and V2 and the surge. Thus the velocities at sections 1 and 2 becomes (V1 – Vw) and (V2 – Vw) respectively.

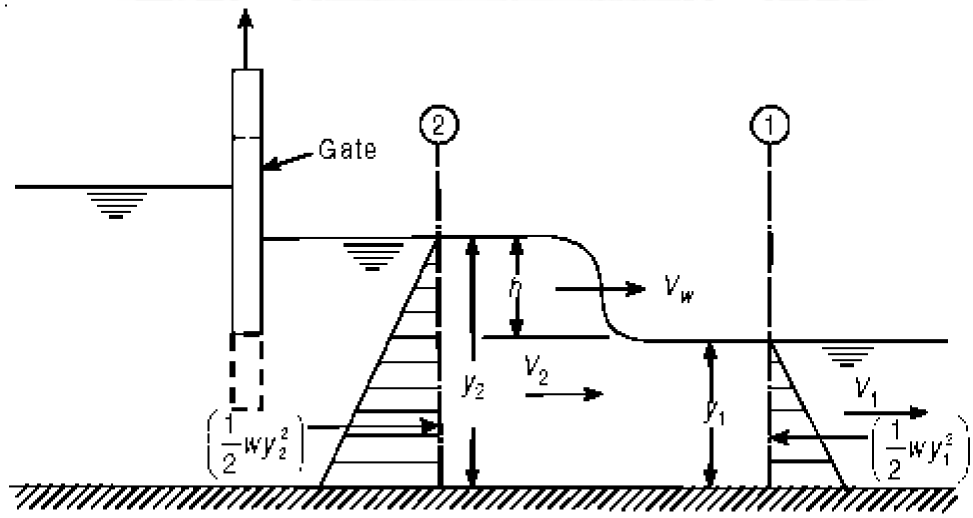

Figure 3.4 positive surges

[*Source: Hydraulics And Fluid Mechanics Including Hydraulic Machines By Dr. P.N.Modi , page 809*]

Case (b) Surge due to sudden reduction of flow

Consider a positive surge of type *B* created in a rectangular channel by sudden reduction of flow due to partial or complete closing of a gate. If *Vw* is the absolute velocity of the surge moving towards left then in order to make it a case of steady flow apply a velocity V_w in the direction opposite to that of surge. The velocities at sections 1 and 2 will then be $(V_1 + V_w)$ and $(V_2 + V_w)$ respectively. The continuity equation in this case is

$$y_1(V_1 + V_w) = y_2(V_2 + V_w)$$

Negative Surges

Negative surges are not stable in form because as indicated below the upper portions of the wave travel faster than the lower portions. if y_2 is the depth below the top a_1 b_1 of the wave and y_1 is the depth below the bottom or trough c_1 d_1 of the wave, then since celerity $C = gy$, its value at the top a_1 b_1 of the wave is $C_2 = gy_2$ and at the bottom c_1 d_1 of the wave is $C_1 = gy_1$; and C_2 is greater than C_1. Thus if the initial profile of the surge is assumed to have a steep front, it will soon flatten out as the surge moves through the channel. If the height of the surge is moderate or small compared with the depth of flow, the equations derived for a positive surge can be applied to determine approximately the propagation of the negative surge. However, if the height of the surge is relatively large, a more elaborate analysis as indicated below may be adopted.